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FUTURE PROSPECTS FOR THE USE OF TELEVISION MICROSCOPY TO DETECT EXTRATERRESTRIAL LIFE

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FUTURE PROSPECTS FOR THE USE OF TELEVISION MICROSCOPY TO DETECT EXTRATERRESTRIAL LIFE

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The most important factors responsible for the initiation and wide development of television microscopy as an independent trend in scientific research in both Earth and space laboratories are considered. /2*

Since television microscopy is one of the most informative techniques for studying microstructures, one of the immediate tasks is the complete automation of all systems. Material is presented which demonstrates the necessity for using special systems of automatic focusing of microimages.

To solve these problems, the establishment of the necessary and sufficient signs of life is required.

The steady increase of the requirements placed on one of the most important methods of studying biostructures — optical microscopy — was the reason for the initiation in the last few years of a new trend called television microscopy. At present, the television microscope is a device containing a television system integrated with a special optical microscope. The instrument is intended to obtain various qualitative and quantitative data about the object being studied, including its image, and can operate in a wide range of wavelengths — from infrared to the ultraviolet. /3

As is known [1], [2], the basic factors responsible for the feasibility of concurrent use of radio engineering, electronic and microscopy methods in laboratories on the Earth are:

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*Numbers in the margin indicate pagination in the original foreign text.

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1. Sharp reduction of illumination of the object under study during the experiment. This has special importance in studies in ultraviolet rays which, on the one hand, have a specifically strong destructive effect on the preparation, but, on the other hand, provide greatly increased contrast of the image and heightened resolving power of the optics.

2. Obtaining preliminary data on the chemical composition of the object /4 and topography of the distribution of particular materials in its structure. To obtain these data, the fairly critical relation of the absorption coefficient of organic components to light wavelength is used (absolute values of absorption are 5-10 times greater at the maximum than at the minimum [3]).

3. Indications of the presence of exchange of matter by comparing images obtained in the same light, but at various times.

4. Making various quantitative measurements with great precision (plotting absorption curves, determining dimensions of image details, etc.).

In making space experiments on planets, the task of automatic biological stations is to detect life or its traces with the greatest possible reliability. In conducting an experiment in space, the short communication time, very serious limitations on weight, size, amount of consumable power, and a number of other reasons put in the forefront the following important problems, on whose solution the success of the entire experiment as a whole might depend:

(1) complete (or nearly complete) automatic operation of the equipment;

(2) automatic analysis of information obtained (even though preliminary) to select data which should be transmitted to Earth.

In relation to television microscopy, the most important part of problem /5 No. 1 is automatic focussing of the optical system. If it is inaccurately set, each point of the object will no longer be in the center of the sphere formed by the image. As a result, the image of that point will be formed by rays whose paths are not identical. According to the Rayleigh criterion, if the maximum difference of paths Δmax does not exceed 1/4 of the light wavelength, the image can be considered focussed. In practice, however, it is more convenient to deal not with Δmax, calculated according to that criterion, but with another value — the probable error of positioning the object in relation to the optical system ε_{gon} [4]. Results of such conversion for the field of view are given in the table. Here $n \cdot \sin \mu$ is the numerical aperture.

$n \cdot \sin U$	0,50	0,75	I,00	I,25
$2\varepsilon_{gon}$, μm	3	I,3	0,7	0,4

Since defocussing can be done in both directions from the positioning point of the object, the second column indicates duplicate values of the permissible error.

These data quite obviously indicate that attempts to rigidly the optical system and variable parameters — and in this way to eliminate the necessity for optical adjustment when using the classical scheme of biological microscopy — are evidently doomed to failure.

Several versions of devices to automatically focus optical images in /6
transmitting television cameras have been suggested and developed [5]. The detail D of a multi-gradation television picture, calculated for frame period T_K, is usually used as an accuracy characteristic. If the videosignal strength is designated by U(t), then

$$D = \int_0^{T_K} \left| \frac{d[U(t)]}{dt} \right| dt$$

It must be pointed out that the systems described in the literature are complex, cumbersome, and were developed for ordinary television cameras and sometimes need changes in the duplicating transmitting tubes operating only in the focussing device.

Evidently, it is theoretically possible to create television microscopy without any autofocussing system at all. For this, it would be necessary to put the preparation being studied between the light sources and the transmitting tube in direct contact with its photocathode. The resolving power of such a device will basically be determined by a photodetector. For the majority of existing tubes, this is about 20-30 micrometers (the effective diameter of a commutative beam is 10-15 micrometers [6]). At the cost of complicating the apparatus, if necessary, the resolving power can be increased by setting a fibered optics between the photocathode and the preparation. /7
Considering that the minimum size of an elementary filament fiber is 2 micromicrons, their total number is quite high, and the coefficient of magnification is 10 X, which corresponds approximately to the data given in [7]. We find that the resolving power increases by a factor of 8-10. We must point out that actual resolution will depend on the mutual distribution of fine details of the preparation, of the optical filament fibers, and the lines of the television screen. The greatest losses could take place in vertical resolution, as in this direction the television screen has a discrete structure. At worst, the size of the element with vertical resolution increases 3-4 times, and with horizontal resolution it doubles. The probability of this is quite small.

Comparisons of devices with an automatic focussing system and without it, show that, other conditions being the same, the resolution of the first type will always be considerably higher. Actually, in good biological microscopes it is determined by the wave properties of light and for the visible field is about 0.25 micrometers [8]. In systems with fibered optics, accuracy will depend on the size of the fiber, which (separated from purely technological difficulties) proved not to be less than 1-2 micrometers because of diffraction phenomena. As was indicated above, certain errors will also occur because of the discrete structure of the image produced. Therefore, the creation of an automatic focussing system for television microscopes is one of the important and immediate tasks. Perfecting the equipment, making space experiments more complex, and broadening the fields of study in connection with the necessity of solving all the more difficult problems in the last analysis amount to a sharp increase in the information obtained by the station. The problem of detecting life on other planets is one of the most complex problems. To successfully solve it demands organizing a whole list of experiments to obtain a large quantity of the most varied information. It is perfectly evident that the overwhelming majority of this information, in the last analysis, will be excessive. If, for example, certain signs of life are searched for by analyzing microstructure images, then it is very probable that these signs will be detected either in the overwhelming majority of the micro-images obtained (if the experiment is conducted correctly and life is widely distributed at the places of observation), or they will be encountered very rarely or not at all (if the experiment is set up incorrectly or if there is no life in a given place). Each frame of a television micro-image usually consists of about $(2\text{-}5)\cdot 10^5$ points, and the transmission of all the information on board the station would be impossible. As a result, it becomes necessary to reduce the experimental program, which puts the authenticity of the results under some doubt. Under these circumstances, preliminary automatic processing of the information according to certain evaluation criteria and the selection of data to be transmitted to Earth is absolutely necessary and equivalent to the success of the experiment as a whole.

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The creation of computers for preliminary processing of data obtained, however, is a very complicated task. The main difficulties arise because of the absence of the necessary evaluational criteria. Basic signs of life, such as reproduction, growth, activity, response to stimulation, exchange of matter, etc., taken separately, do not give a simple answer to the question, and can always be explained by purely physical or chemical processes. Setting up an experiment to detect life demands, however, a large amount of apriori data as a basis on which to build all research. Thus, successful solution of the problem is possible only after appropriate exobiological research and after clearly establishing necessary and sufficient signs of life.

CONCLUSIONS

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1. Television microscopy, as one of the most informative methods of research, makes it possible to conduct on board the station a whole complex of varied experiments in detecting signs of life on other planets.

2. The specific character of space experiments demands the creation of complete (or nearly complete) automatic television microscopes with sufficiently high qualitative indices. Developing principles for constructing these devices and creating systems for automatic focussing of the optical image are the immediate tasks in this direction.

3. It is impossible to conduct a broad complex of research without preliminary on-board automatic data processing and the selection of data to be transmitted to Earth.

4. Development of equipment control algorithms must be based on the results of exobiological research and clear establishment of necessary and sufficient signs of life.

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